

UTILITY PATENT APPLICATION TRANSMITTAL (Large Entity)

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Docket No.
PO9-99-067

Total Pages in this Submission

108 excluding refs.

TO THE ASSISTANT COMMISSIONER FOR PATENTS

Box Patent Application
Washington, D.C. 20231

Transmitted herewith for filing under 35 U.S.C. 111(a) and 37 C.F.R. 1.53(b) is a new utility patent application for an invention entitled:

RECONFIGURING A NETWORK BY UTILIZING A PREDETERMINED LENGTH QUIESCENT STATE

and invented by:

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If a **CONTINUATION APPLICATION**, check appropriate box and supply the requisite information:

☒ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.: _____

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Enclosed are:

Application Elements

1. ☒ Filing fee as calculated and transmitted as described below
2. ☒ Specification having 35 pages and including the following:
 - a. ☒ Descriptive Title of the Invention
 - b. ☐ Cross References to Related Applications (if applicable)
 - c. ☐ Statement Regarding Federally-sponsored Research/Development (if applicable)
 - d. ☐ Reference to Microfiche Appendix (if applicable)
 - e. ☒ Background of the Invention
 - f. ☒ Brief Summary of the Invention
 - g. ☒ Brief Description of the Drawings (if drawings filed)
 - h. ☒ Detailed Description
 - i. ☒ Claim(s) as Classified Below
 - j. ☒ Abstract of the Disclosure

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68 excluding refs.

Application Elements (Continued)

3. ☒ Drawing(s) (when necessary as prescribed by 35 USC 113)

a. ☒ Formal Number of Sheets 12

b. ☐ Informal Number of Sheets _____

4. ☒ Oath or Declaration

a. ☒ Newly executed (original or copy) ☐ Unexecuted

b. ☐ Copy from a prior application (37 CFR 1.63(d)) (for continuation/divisional application only)

c. ☒ With Power of Attorney ☐ Without Power of Attorney

d. ☐ DELETION OF INVENTOR(S)

Signed statement attached deleting inventor(s) named in the prior application,
see 37 C.F.R. 1.63(d)(2) and 1.33(b).

5. ☐ Incorporation By Reference (usable if Box 4b is checked)

The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

6. ☐ Computer Program in Microfiche (Appendix)

7. ☐ Nucleotide and/or Amino Acid Sequence Submission (if applicable, all must be included)

a. ☐ Paper Copy

b. ☐ Computer Readable Copy (identical to computer copy)

c. ☐ Statement Verifying Identical Paper and Computer Readable Copy

Accompanying Application Parts

8. ☒ Assignment Papers (cover sheet & document(s))

9. ☐ 37 CFR 3.73(B) Statement (when there is an assignee)

10. ☐ English Translation Document (if applicable)

11. ☒ Information Disclosure Statement/PTO-1449 ☒ Copies of IDS Citations

12. ☐ Preliminary Amendment

13. ☐ Acknowledgment postcard

14. ☒ Certificate of Mailing

☐ First Class ☒ Express Mail (Specify Label No.): EJ896412869US

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Accompanying Application Parts (Continued)

15. ☐ Certified Copy of Priority Document(s) *(if foreign priority is claimed)*

16. ☐ Additional Enclosures *(please identify below):*

Fee Calculation and Transmittal

CLAIMS AS FILED

For	#Filed	#Allowed	#Extra	Rate	Fee
Total Claims	52	- 20 =	32	x \$18.00	\$576.00
Indep. Claims	4	- 3 =	1	x \$78.00	\$78.00
Multiple Dependent Claims (check if applicable) <input type="checkbox"/>					\$0.00
BASIC FEE					\$760.00
OTHER FEE (specify purpose)					\$0.00
TOTAL FILING FEE					\$1,414.00

- ☐ A check in the amount of _____ to cover the filing fee is enclosed.
- ☒ The Commissioner is hereby authorized to charge and credit Deposit Account No. **09-0463** as described below. A duplicate copy of this sheet is enclosed.
- ☒ Charge the amount of **\$1,414.00** as filing fee.
- ☒ Credit any overpayment.
- ☐ Charge any additional filing fees required under 37 C.F.R. 1.16 and 1.17.
- ☐ Charge the issue fee set in 37 C.F.R. 1.18 at the mailing of the Notice of Allowance, pursuant to 37 C.F.R. 1.311(b).


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Docket No: PO9-99-067

RECONFIGURING A NETWORK BY
UTILIZING A PREDETERMINED
LENGTH QUIESCENT STATE

APPLICATION FOR
UNITED STATES LETTERS PATENT

Express Mail Label No: EJ896412869US

Date of Deposit: October 4, 1999

I hereby certify that this correspondence is being deposited with the United States Postal Service as Express Mail Post Office to Addressee Service under 37 CFR 1.10 on the date indicated above and is addressed to Box Patent Application, Commissioner of Patents and Trademarks, Washington, D. C. 20231.

Susan L. Nelson

Susan L. Nelson

I N T E R N A T I O N A L B U S I N E S S M A C H I N E S
C O R P O R A T I O N

RECONFIGURING A NETWORK BY UTILIZING
A PREDETERMINED LENGTH QUIESCENT STATE

Technical Field

5 This invention relates, in general, to the reconfiguration of a network of a computing system. More particularly, this invention relates to reconfiguring a network having a plurality of nodes to reflect a change in topology of the network by utilizing a predetermined length quiescent state.

10 Background Art

Typically, a distributed computing environment or computing system includes a number of processors or nodes interconnected to one another via one or more links to form a system of networks. This network of nodes is then able to process tasks concurrently in a manner which is more effective than with nodes processing individually.

15 In order to allow the nodes of these computing systems to process tasks in such a manner, monitoring systems are implemented within the computing systems to monitor the status of the nodes and their network adapters. These monitoring systems typically monitor the computing system for the failure or activation of nodes within the system. Thus, if a node or network adapter in such a computing system were to fail, the monitoring system would be responsible for identifying the failed node and for informing the remainder of the nodes of the failure.

From time to time, configuration changes are required to be implemented in computing systems operating under these monitoring systems due to, for example, the addition or deletion of computing resources (either individual nodes or entire networks of nodes) or due to, for example, address changes of network adapters. One possible procedure for implementing configuration changes requires the monitoring system to be deactivated and restarted only after the new configuration has been implemented. However, the deactivation of the monitoring system greatly inconveniences the subsystems relying on the monitoring system.

An alternate procedure is to implement configuration changes by performing a global synchronization. However, with a global synchronization each node in the computing system is required to be directly connected to each of the other nodes. Additionally, if the nodes in the computing system belong to different networks, a multiple hop communication is required for messages between some of the nodes. Furthermore, global synchronization also detrimentally interrupts any protocols running when reconfiguration is initiated.

As yet another alternative, nodes operating under the monitoring system may be reconfigured individually without deactivating the entire system. However, this procedure results in the danger of the transmission of messages from a node operating one configuration to nodes operating under another configuration, and because the contents of some messages are valid only when exchanged between nodes having the same view of the system, this procedure oftentimes leads to disastrous results.

In high availability systems, the above-mentioned disadvantages are unacceptable. Thus, a need exists for a reconfiguration protocol which allows reconfiguration without interruption to executing protocols. In addition, a further need exists for a reconfiguration protocol which implements a new configuration without requiring global synchronization.

Summary Of The Invention

The shortcomings of the prior art are overcome and additional advantages are provided through the provision of a method for reconfiguring a network having a plurality of nodes to reflect a change in topology of the network. In one example, the method includes: upon receiving a reconfiguration request at one node of said plurality of nodes, entering a quiescent state at said one node, wherein said one node remains in said quiescent state for a predetermined period of time sufficient to allow at least one other node of said plurality of nodes to also enter a quiescent state; and upon termination of said quiescent state at said one node, reconfiguring said one node to reflect said change in topology of said network without checking with said at least one other node.

In another embodiment, a system for reconfiguring a network having a plurality of nodes to reflect a change in topology of the network includes: means for entering, upon receiving a reconfiguration request at one node of said plurality of nodes, a quiescent state at said one node, wherein said one node remains in said quiescent state for a predetermined period of time sufficient to allow at least one other node of said plurality of nodes to also enter a quiescent state; and means for reconfiguring, upon termination of said quiescent state at said

one node, said one node to reflect said change in topology of said network without checking with said at least one other node.

5 In yet another embodiment, another system for reconfiguring a network having a plurality of nodes to reflect a change in topology of the network includes: a computing node capable of, upon receiving a reconfiguration request at one node of said plurality of nodes, entering a quiescent state at said one node, wherein said one node remains in said quiescent state for a predetermined period of time sufficient to allow at least one
10 other node of said plurality of nodes to also enter a quiescent state; said computing node further being capable of upon termination of said quiescent state at said one node, reconfiguring said one node to reflect said change in topology of said network without checking with said at least one other node.

15 In still yet another embodiment, an article of manufacture comprising a computer useable medium having computer readable program code means embodied therein for reconfiguring a network having a plurality of nodes to reflect a change in topology of the network includes: computer readable program code means for
20 entering, upon receiving a reconfiguration request at one node of said plurality of nodes, a quiescent state at said one node, wherein said one node remains in said quiescent state for a predetermined period of time sufficient to allow at least one other node of said plurality of nodes to also enter a quiescent
25 state; and computer readable program code means for reconfiguring upon termination of said quiescent state at said one node, said one node to reflect said change in topology of said network without checking with said at least one other node.

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The reconfiguration capability of the present invention advantageously enables a network having a plurality of nodes to be reconfigured to reflect a change in topology of the network by utilizing a predetermined length quiescent state. In one
5 embodiment, this predetermined period of time is sufficient to allow the transmission of reconfiguration requests from one node to other nodes of the network thereby causing the other nodes to also enter quiescent states. In another embodiment, this predetermined period of time is sufficient for protocols
10 currently running on the network to complete execution. By utilizing this predetermined period of time, each node is able to exit from or terminate its quiescent state without having to check with or receive any communication from the other nodes of the network. Consequently, currently executing protocols are not
15 interrupted and global synchronization is not required.

Additional features and advantages are realized through the techniques of the present invention. Other embodiments and aspects of the invention are described in detail herein and are considered a part of the claimed invention.

Brief Description Of The Drawings

20 The subject matter which is regarded as the invention is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other objects, features, and advantages of the invention are apparent
25 from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 depicts one example of a computing system incorporating and using a reconfiguring capability of the present invention;

FIG. 2 depicts one example of a configuration file used with the reconfiguring capability of the present invention;

FIG. 3 depicts one example of computing system and transmission of a heartbeat message, in accordance with the principles of the present invention;

FIGS. 4a-4g depict one example of the execution of a join protocol, in accordance with the principles of the present invention;

FIG. 5 depicts one example of the execution of a death protocol, in accordance with the principles of the present invention;

FIGS. 6a-6b depict one example of the execution of a node reachability protocol, in accordance with the principles of the present invention;

FIG. 7 depicts one example of a state diagram of a node of FIG. 1, in accordance with the principles of the present invention;

FIG. 8 depicts one example of a packet transmitted by the nodes of FIG. 1, in accordance with the principles of the present invention;

FIG. 9 depicts one example of a time line illustrating the operation of the system of FIG. 1, in accordance with the principles of the present invention; and

FIGS. 10a-10b depict one example of a flow diagram associated with the reconfiguration capability of the present invention.

Best Mode For Carrying Out The Invention

5 In accordance with the principles of the present invention, a network having a plurality of nodes is reconfigured to reflect a change in topology of the network by utilizing a predetermined length quiescent state. In one embodiment, this predetermined period of time is sufficient to allow the transmission of
10 reconfiguration requests from one node to other nodes of the network thereby causing the other nodes to also enter quiescent states. In another embodiment, this predetermined period of time is sufficient for protocols currently running on the network to complete execution. By utilizing this predetermined period of
15 time, each node is able to exit from or terminate its quiescent state without having to check with or receive any communication from the other nodes of the network.

FIG. 1 depicts one example of a distributed computing system incorporating the reconfiguring capability of the present
20 invention. In one embodiment, a distributed computing system 100 includes a number of interconnected processors or nodes 101, 102, 103, and 104. Each of these nodes may be, for example, a RS/6000 offered by International Business Machines Corporation, or in the alternative each node may be a single processing node of a
25 RS/6000 SP also offered by International Business Machines Corporation.

Nodes 101, 102, 103, and 104, in turn, are each bound to a network adapter, which may be, for example, an SP Switch adapter,

and connected to a link. Associated with each adapter is an address (e.g., an IP address), which is used to locate the nodes on the links and to effect communication therebetween. Together, these links and adapters collectively form a network, which may be, for example, an Ethernet or the like. Thus, in FIG. 1, nodes 101, 102 and 104 are coupled to a link via their respective network adapters, and these network adapters together with the link to which they are coupled collectively form network 110. Likewise, networks 120 and 130 are similarly comprised of their respective links and the adapters of nodes 101, 102, 103, and 104.

By interconnecting nodes 101, 102, 103, and 104 in this manner, each node is capable of communicating with other nodes through the transmission of packets or messages. One example of a message capable of being transmitted between nodes is depicted in FIG. 8. In particular, FIG. 8 shows the format of a typical message 800 in which data is separated into a number of fields. Each of these fields contains various types of data which are to be transmitted to the other nodes. For instance, the message in FIG. 8 includes: a configuration instance identifier 810; the packet type information 820; the sending adapter identification 830; the sending group identification 840; the destination adapter identification 850; the destination group identification 860; the length of variable length data 870; and the variable length data itself 880.

The status and operation of the nodes in computing system 100 are monitored by a node and network adapter monitoring system. As one example, this system may be Topology Services offered by International Business Machines Corporation. As may be evident from the name of this particular system, these systems

are generally used to maintain and disseminate information regarding the topology, or layout, of a computing environment in which it is implemented. For instance, Topology Services is responsible for monitoring events, such as, for example, activation or deactivation of nodes and network adapters. Topology Services informs its client programs about the set of nodes and network adapters in the system that are seen as operational. In addition, Topology Services monitors the addition or removal of nodes, networks, or network adapters and also any changes in the addresses of network adapters. Furthermore, although Topology Services is used in this example for illustrative purposes, it is to be understood that the concepts of the present invention are equally applicable to other similar node and network adapter monitoring systems.

To accomplish its goal of monitoring the nodes of computing system 100, Topology Services runs a process or daemon at each node in computing system 100. Utilizing these daemons, Topology Services is able to run a number of network adapter protocols across each network being monitored.

Referring to FIG. 2, Topology Services also makes use of a configuration file 200 which, in one embodiment, is located on a database accessible by each of the nodes in computing system 100. In the alternative, in another embodiment, the configuration file may be located in local memory or a local file of each node. In any event, as shown in FIG. 2, the configuration file contains, for instance, information regarding the configuration of the system, such as an identifier representing a system configuration 210, global tunable values 230, a list of all the adapters in each network and information regarding the network adapter addresses and the like 240.

This configuration file is read by each node at startup or system initialization. In addition to this initial read of the configuration file, each reconfiguration, or change in configuration to the system, also causes each node to read the configuration file. Furthermore, in order to facilitate the dissemination of accurate data, the configuration file is updated, for instance by a system user or at the direction of the system itself, with each modification to the system. As will be discussed below, this configuration file is used in reconfiguring the networks of the system to reflect any changes in topology.

Referring to FIG. 3, as one example of a protocol available to Topology Services, a heartbeat protocol is used to identify a set or group of adapters and nodes 310 which are operational or alive in each network. More particularly, each adapter membership group is organized with its members in a virtual ring topology. At predetermined intervals, each node transmits a heartbeat message 350 to a downstream node. This heartbeat message 350 is, in turn, monitored by each of the downstream nodes. In this manner, the cessation of heartbeat messages from a node, beyond a preset number or a predetermined period of time, is recognizable as a node failure by its downstream neighbor.

In FIGS. 4a-4g Topology Services utilizes, as another example, a join protocol to add individual nodes or entire adapter membership groups to an existing membership group. In order to utilize this join protocol, Topology Services first designates a group leader for each membership group. This group leader is a node responsible for coordinating a membership group's protocols and is determined by a predefined adapter priority rule, such as, for instance, using an adapter having the highest IP address.

As an example of the execution of the join protocol, in FIGS. 4a-4g a system 410 includes two individual adapter membership groups 420 and 430. Upon commencement of the join protocol, a group leader GL1 of membership group 420 transmits a
5 proclaim message 450 to all adapters outside the sender's group having a lower IP address, which is ignored by all adapters that are not group leaders. A group leader of membership group 430 receives proclaim message 450, and responds with a join message 460, which contains a membership list of group 430. Thus in FIG.
10 4b, group leader GL2 transmits a join message 460 containing a list of each of the members of its group to group leader GL1.

In FIG. 4c, subsequent to receiving join message 460, group leader GL1 transmits a prepare to commit (PTC) message 470 to all of the nodes listed in join message 460 as well as to the members
15 of its own membership group. In response as shown in FIG. 4d, nodes receiving PTC message 470 reply with an acknowledgment or PTC ACK message 480 to group leader GL1. Then, a new group 440 is formed comprising all of the nodes from which a PTC ACK message is received.

In order to disseminate new group membership information to each of the nodes, in FIG. 4e group leader GL1 transmits a commit
20 broadcast (COMMIT BCAST) message 485 to a number of mayor nodes (determined in a manner similar to the determination of the group leaders). Turning to FIG. 4f, the mayor nodes then transmit
25 commit messages 490 to all members in a subgroup for which each mayor is responsible. By utilizing this two-phase transmission procedure, the speed at which the membership information is disseminated may be increased.

Receipt of the commit message marks the transition from the two individual membership groups to the single newly formed group 440, as depicted in FIG. 4g. At this time, group leader GL1 begins transmitting heartbeat messages as well as proclaim messages, both of which were discussed above.

On a further note, it is altogether possible that a number of the messages utilized by Topology Services' protocols may not reach their intended destination during their first attempts. Thus, many of the messages are transmitted a multiple number of times. For instance, in one embodiment, each of the PTC, commit BCAST, and commit messages are repeatedly transmitted until an acknowledgment is received or until a predetermined number of attempts has been exceeded (i.e., a predetermined number of retries). To illustrate, a PTC message may be transmitted, for example twenty times (i.e., twenty retries) or until an acknowledgment is received. In this manner, the probability of a message reaching its intended destination is increased.

As discussed above, each node monitors heartbeat messages to determine whether its upstream neighbor is operational. When a predetermined period of time elapses without the receipt of a heartbeat message (thus signifying that the upstream neighbor is no longer operational), a death protocol is executed. Referring to FIG. 5, after the absence of a period of time in which no heartbeat messages have been received, a node 520 recognizes that its upstream neighbor 525 has died. Node 520 then initiates the death protocol by transmitting a death message 550 to a group leader GL of its membership group 510.

Upon receipt of the death message, group leader GL transmits a PTC message which is followed by the remainder of the join

protocol, as discussed above, to form a new group comprising all of the members of the old group except the dead node.

Another example of a protocol available to Topology Services is a node reachability protocol. The node reachability protocol determines a complete set of reachable (or alive) nodes and disseminates this information to each of the nodes of the system. The importance of this feature becomes evident when one realizes that the computing system of the present invention can potentially span several networks thereby requiring communication between some nodes to occur through a sequence of multiple network hops. This particular protocol is implemented through two messages, a node connectivity and a group connectivity message, which are discussed in greater detail below.

Referring to FIG. 6a, a node connectivity message 620 is sent from each node in a membership group to the group's group leader GL1. These node connectivity messages contain information regarding the networks to which the sending node is connected, or in other words information regarding all of the other membership groups to which the sending node belongs. Subsequently, group leader GL1 stores this information in local memory and responds with the transmission of a group connectivity message 630 to all of the members of its group (see, FIG. 6b). In contrast to the information contained in the node connectivity message, the group connectivity message contains aggregate information collected from all of the node connectivity messages received from the group members. Furthermore, to ensure that the group connectivity message information is disseminated to all of the nodes of the system, each node then forwards the group connectivity message to all nodes that are reachable via networks other than the network from which the message was initially

received. In this manner, each node is made aware of all of the reachable nodes of the system.

In accordance with one aspect of the present invention, a reconfiguration protocol is provided for implementing configuration changes to the system. These configuration changes, or reconfigurations, are implemented in each node to reflect changes in the topology of the system. Thus, for example, reconfiguration occurs with the addition or removal of computing resources, such as, for instance, a single node or an entire network of nodes, to the existing system or with, for example, a change in the address or addition or removal of an adapter. Furthermore, since reconfiguration may be necessitated at any time, even in the middle of an executing protocol, the reconfiguration should be made with minimal disturbance to the system and also without interruption to executing protocols.

To implement this particular protocol, information relating to the topology of the configuration, as well as a configuration identifier representing the configuration of the system, is written to the configuration file of FIG. 2 with each event that changes the configuration of the system. As discussed above, this configuration file is then read by each node at the commencement of reconfiguration. After reading the configuration file, each node stores this information to local memory. The configuration identifier is then utilized to trigger reconfiguration, as discussed in greater detail below.

Referring to FIGS. 9 and 10, reconfiguration is typically initiated by a user, locally, at a particular node, 910 and 1010. As part of a user initiated reconfiguration, new configuration information, including a new configuration identifier is stored

to the configuration file. In addition, reconfiguration at a particular node may be triggered by the receipt of a message having a reconfiguration sequence identifier (e.g., a number equal to the maximum possible value of the system) 915 and 1015. In any event, the node that receives the reconfiguration request (from either a user or in the form of a message) responds by reading the configuration file containing the new configuration information, 920 and 1020, and stores this new information to local memory. However, instead of immediately implementing the configuration changes, the node enters a quiescent state for a predetermined period of time, 925 and 1025.

In particular, each node remains in a quiescent state for a period of time sufficient to allow currently running protocols to complete execution under the previous configuration. In addition, the quiescent state is set to allow the propagation of messages containing a reconfiguration sequence identifier to the other nodes of the system, and thus trigger reconfiguration in those other nodes as well, 915 and 1015. Therefore, before the quiescent state terminates at an individual node, all currently running protocols (e.g., death or join protocols) will have completed execution, and all of the other nodes in the system will have received a reconfiguration request and thus will have also entered their own respective quiescent states. Hence, by using a predetermined period of time, each node may terminate its quiescent state without any express communication or acknowledgment from any other nodes.

As discussed above, upon receiving a reconfiguration request, each node enters a quiescent state for a predetermined period of time sufficient to allow currently running protocols to complete execution under the previous configuration.

Specifically, each protocol is set so that execution completes after a limited amount of retries are performed with a set period of time between retries. To use the join protocol as an example, a group leader attempting to have a new node commit will transmit only a limited amount of PTC messages, for example, twenty, with, for example, three seconds between the transmission of each PTC message. Thus, in this example, assuming that the join protocol is the lengthiest protocol utilized by the system, the predetermined period of the quiescent state is set to cover, at least, 60 seconds (20 retries X 3 seconds between each retry).

Furthermore, while in this quiescent state, each node also propagates reconfiguration requests to the other nodes of the system (see, 915 and 1030). In accordance with the principles of the invention, the system utilizes a slightly modified message belonging to another protocol to facilitate the propagation of these reconfiguration requests. More specifically, messages such as, for instance, proclaim, node connectivity, or group connectivity messages are modified to include the aforementioned reconfiguration sequence identifier (e.g., a number equal to the maximum possible value of the system). Additionally, in other embodiments, the frequency of transmission of some messages may be increased to further increase the rate of propagation. Then, upon receipt of these messages by the other nodes of the system, reconfiguration is triggered in those other nodes as well (see, 1015).

To ensure that new configurations are not observed before the other nodes of the system have had an opportunity to initiate reconfiguration, nodes in their quiescent states do not process messages with sequence identifiers different from the sequence identifier currently stored in local memory. In addition, some

protocol messages are ignored during the quiescent state to prevent new protocols from executing. When the quiescent state ends and data structures are modified, no protocols are executing which makes the data structure changes much simpler and safer.

5 For instance, proclaim, join, node connectivity, and group connectivity messages are all ignored during the quiescent state. Heartbeat messages are also not monitored so that nodes which have temporarily stopped transmitting heartbeats are not mistakenly considered not operational. Furthermore, messages of
10 not yet completed protocols are transmitted with the previous configuration identifier and not with the reconfiguration sequence identifier. Heartbeat messages, on the other hand, are transmitted with the reconfiguration sequence identifier to help propagate the reconfiguration request. However, the heartbeat
15 message is nevertheless accepted even when the sequence identifier does not match that of the receiver.

After the quiescent state has terminated 1035, as dictated by the period of time required for all of the executing protocols to terminate and for reconfiguration requests to be propagated to
20 the other nodes of the system, each node implements the new configuration read from the configuration file, by performing data structure changes to reflect the change in topology, 930 and 1040. Subsequently, each node enters a grace period, 935 and 1050, as discussed below.

25 Because nodes of the system typically do not enter their quiescent states at the same time, the aforementioned grace period is used to allow all nodes to exit their quiescent states before any nodes resume normal operation. In this regard, the grace period, in one example, is equal to the length of the
30 quiescent state. Furthermore, during the grace period, each node

transmits messages with the new configuration identifier 940,
begins honoring messages with the new configuration identifier
(and initiating any new protocols as a result of these messages),
and transmits protocol messages that normally have a limited
amount of retries throughout the entire grace period 1055.
Additionally, messages having configuration numbers different
from the new configuration number are ignored and heartbeat
messages are not monitored, and no computation is made of the set
of reachable nodes 1055.

Subsequently, after a period of time equal to the duration
of the grace period has elapsed 945, normal operation is resumed
(i.e., the set of reachable nodes is computed, any limits to the
maximum number of retries is again enforced, and the monitoring
of heartbeat messages is commenced, 950 and 1065).

Referring to FIG. 7, a state diagram of a particular node is
depicted. As can be seen, a local reconfiguration request 715 or
a message with a reconfiguration sequence identifier 720 causes
the node to exit a normal operational state 710 and enter a
quiescent state 725. Then, after termination of the quiescent
state, the node enters a grace period 730. Similarly, after
termination of the grace period, the node returns to normal
operation 710.

Although reconfiguration requests are shown as being
triggered by messages having a reconfiguration sequence
identifier, it is also possible for reconfiguration to be
triggered by a message having a sequence identifier differing
from that which is stored in the receiving node. In this case, a
node may be deactivated when reconfiguration occurs in the other
nodes. Then, when the node is later reactivated, it will

initially start operating with the old configuration, only to be reconfigured upon the receipt of a message having a different or new sequence identifier.

Thus, presented herein is a reconfiguration capability which advantageously enables a network having a plurality of nodes to be reconfigured to reflect a change in topology of the network by utilizing a predetermined length quiescent state. This predetermined period of time is sufficient to allow the transmission of reconfiguration requests from one node to other nodes of the network thereby causing the other nodes to also enter quiescent states. In another embodiment, this predetermined period of time is sufficient for protocols currently running on the network to complete execution. By utilizing this predetermined period of time, each node is able to exit from or terminate its quiescent state without having to check with or receive any communication from the other nodes of the network. Consequently, currently executing protocols are not interrupted and global synchronization is not required.

The present invention can be included in an article of manufacture (e.g., one or more computer program products) having, for instance, computer usable media. The media has embodied therein, for instance, computer readable program code means for providing and facilitating the capabilities of the present invention. The article of manufacture can be included as a part of a computer system or sold separately.

Additionally, at least one program storage device readable by a machine, tangibly embodying at least one program of instructions executable by the machine to perform the capabilities of the present invention can be provided.

The flow diagrams depicted herein are just exemplary. There may be many variations to these diagrams or the steps (or operations) described therein without departing from the spirit of the invention. For instance, the steps may be performed in a differing order, or steps may be added, deleted or modified. All of these variations are considered a part of the claimed invention.

Although preferred embodiments have been depicted and described in detail herein, it will be apparent to those skilled in the relevant art that various modifications, additions, substitutions and the like can be made without departing from the spirit of the invention and these are therefore considered to be within the scope of the invention as defined in the following claims.

Claims

What is claimed is:

1 1. A method of reconfiguring a network having a plurality
2 of nodes to reflect a change in topology of said network, said
3 method comprising:

4 upon receiving a reconfiguration request at one node of
5 said plurality of nodes, entering a quiescent state at said one
6 node, wherein said one node remains in said quiescent state for a
7 predetermined period of time sufficient to allow at least one
8 other node of said plurality of nodes to also enter a quiescent
9 state; and

10 upon termination of said quiescent state at said one
11 node, reconfiguring said one node to reflect said change in
12 topology of said network without checking with said at least one
13 other node.

1 2. The method of claim 1, wherein said predetermined
2 period of time comprises an amount of time sufficient to transmit
3 a reconfiguration request from said one node to said at least one
4 other node, wherein receipt of said reconfiguration request
5 causes said at least one other node to enter a quiescent state.

1 3. The method of claim 1, wherein said predetermined
2 period of time comprises an amount of time sufficient for
3 protocols currently running on said network to complete
4 execution.

1 4. The method of claim 3, wherein said protocols comprise
2 one of a heart beat, join, death, or node reachability protocol.

1 5. The method of claim 1, wherein said predetermined
2 period of time comprises an amount of time sufficient for a
3 protocol currently running on said network to perform a
4 predetermined number of retries plus a predetermined amount of
5 time between each retry, wherein after attempting said
6 predetermined number of retries, said protocol completes
7 execution.

1 6. The method of claim 5, wherein said protocol comprises
2 one of a heart beat, join, death, or node reachability protocol.

1 7. The method of claim 1, wherein said reconfiguring said
2 one node occurs without any communication to said node from said
3 at least one other node of said plurality of nodes.

1 8. The method of claim 1, wherein said reconfiguring said
2 one node comprises refraining from observing said change in
3 topology at said one node during a grace period, wherein said
4 grace period comprises a predetermined period of time sufficient
5 to allow said at least one other node of said plurality of nodes
6 to exit a quiescent state, and upon termination of said grace
7 period, observing said change in topology at said one node.

1 9. The method of claim 1, wherein said reconfiguration
2 request results from addition or removal of a node or of at least
3 one other network to said network.

1 10. The method of claim 1, where said reconfiguration
2 request results from a change in address of a node of said
3 network.

1 11. The method of claim 1, wherein said network is
2 reconfigured without interrupting currently executing protocols.

1 12. The method of claim 1, wherein said network is
2 reconfigured without a global synchronization protocol.

1 13. The method of claim 1, further comprising transmitting,
2 upon entering said quiescent state, a reconfiguration request
3 from said one node to said at least one other node, wherein
4 receipt of said reconfiguration request causes said at least one
5 other node to enter a quiescent state.

1 14. The method of claim 13, wherein said reconfiguration
2 request comprises one of a message having a reconfiguration
3 sequence identifier and a message having a configuration sequence

4 identifier different from a configuration identifier of said one
5 node.

1 15. The method of claim 1, wherein said network comprises a
2 plurality of interconnected computing networks together
3 implementing a distributed node and adapter status monitoring
4 system.

1 16. The method of claim 1, further comprising preventing,
2 by said node when in said quiescent state, execution of new
3 protocols by ignoring proclaim, join, node connectivity, and
4 group connectivity messages and by no longer monitoring heartbeat
5 messages.

1 17. The method of claim 1, further comprising transmitting,
2 by said node when in said quiescent state, proclaim, heartbeat,
3 node connectivity, and group connectivity messages with a
4 reconfiguration sequence identifier to propagate reconfiguration
5 requests to said at least one other node.

1 18. A system for reconfiguring a network having a plurality
2 of nodes to reflect a change in topology of said network, said
3 system comprising:

4 means for entering, upon receiving a reconfiguration
5 request at one node of said plurality of nodes, a quiescent state
6 at said one node, wherein said one node remains in said quiescent
7 state for a predetermined period of time sufficient to allow at
8 least one other node of said plurality of nodes to also enter a
9 quiescent state; and

10 means for reconfiguring, upon termination of said
11 quiescent state at said one node, said one node to reflect said
12 change in topology of said network without checking with said at
13 least one other node.

1 19. The system of claim 18, wherein said predetermined
2 period of time comprises an amount of time sufficient to transmit
3 a reconfiguration request from said one node to said at least one
4 other node, wherein receipt of said reconfiguration request
5 causes said at least one other node to enter a quiescent state.

1 20. The system of claim 18, wherein said predetermined
2 period of time comprises an amount of time sufficient for
3 protocols currently running on said network to complete
4 execution.

1 21. The system of claim 20, wherein said protocols comprise
2 one of a heart beat, join, death, or node reachability protocol.

3 22. The system of claim 18, wherein said predetermined
4 period of time comprises an amount of time sufficient for a
5 protocol currently running on said network to perform a
6 predetermined number of retries plus a predetermined amount of
7 time between each retry, wherein after attempting said
8 predetermined number of retries, said protocol completes
9 execution.

1 23. The system of claim 22, wherein said protocol comprises
2 one of a heart beat, join, death, or node reachability protocol.

1 24. The system of claim 18, wherein said means for
2 reconfiguring said one node reconfigures without any
3 communication to said node from said at least one other node of
4 said plurality of nodes.

1 25. The system of claim 18, wherein said means for
2 reconfiguring said one node comprises means for refraining from
3 observing said change in topology at said one node during a grace
4 period, wherein said grace period comprises a predetermined
5 period of time sufficient to allow said at least one other node
6 of said plurality of nodes to exit a quiescent state, and upon
7 termination of said grace period, for observing said change in
8 topology at said one node.

1 26. The system of claim 18, wherein said reconfiguration
2 request results from addition or removal of a node or of at least
3 one other network to said network.

1 27. The system of claim 18, where said reconfiguration
2 request results from a change in address of a node of said
3 network.

1 28. The system of claim 18, wherein said network is
2 reconfigured without interrupting currently executing protocols.

1 29. The system of claim 18, wherein said network is
2 reconfigured without a global synchronization protocol.

1 30. The system of claim 18, further comprising means for
2 transmitting, upon entering said quiescent state, a
3 reconfiguration request from said one node to said at least one
4 other node, wherein receipt of said reconfiguration request
5 causes said at least one other node to enter a quiescent state.

1 31. The system of claim 30, wherein said reconfiguration
2 request comprises one of a message having a reconfiguration
3 sequence identifier or a message having a configuration sequence
4 identifier different from a configuration identifier of said one
5 node.

1 32. The system of claim 18, wherein said network comprises
2 a plurality of interconnected computing networks together
3 implementing a distributed node and adapter status monitoring
4 system.

1 33. The system of claim 18, further comprising means for
2 preventing, by said node when in said quiescent state, execution
3 of new protocols by ignoring proclaim, join, node connectivity,
4 and group connectivity messages and by no longer monitoring
5 heartbeat messages.

1 34. The system of claim 18, further comprising means for
2 transmitting, by said node when in said quiescent state,
3 proclaim, heartbeat, node connectivity, and group connectivity
4 messages with a reconfiguration sequence identifier to propagate
5 reconfiguration requests to said at least one other node.

1 35. A system for reconfiguring a network having a plurality
2 of nodes to reflect a change in topology of said network, said
3 system comprising:

4 a computing node capable of entering, upon receiving a
5 reconfiguration request at one node of said plurality of nodes, a
6 quiescent state at said one node, wherein said one node remains
7 in said quiescent state for a predetermined period of time
8 sufficient to allow at least one other node of said plurality of
9 nodes to also enter a quiescent state; said computing node
10 further being capable of reconfiguring, upon termination of said
11 quiescent state at said one node, said one node to reflect said
12 change in topology of said network without checking with said at
13 least one other node.

1 36. An article of manufacture comprising:

2 a computer useable medium having computer readable program
3 code means embodied therein for reconfiguring a network having a
4 plurality of nodes to reflect a change in topology of said
5 network, said article of manufacturing comprising:

6 computer readable program code means for entering, upon
7 receiving a reconfiguration request at one node of said plurality
8 of nodes, a quiescent state at said one node, wherein said one
9 node remains in said quiescent state for a predetermined period
10 of time sufficient to allow at least one other node of said
11 plurality of nodes to also enter a quiescent state; and

12 computer readable program code means for reconfiguring, upon
13 termination of said quiescent state at said one node, said one
14 node to reflect said change in topology of said network without
15 checking with said at least one other node.

1 37. The article of manufacturing of claim 36, wherein said
2 predetermined period of time comprises an amount of time
3 sufficient to transmit a reconfiguration request from said one
4 node to said at least one other node, wherein receipt of said
5 reconfiguration request causes said at least one other node to
6 enter a quiescent state.

1 38. The article of manufacturing of claim 36, wherein said
2 predetermined period of time comprises an amount of time
3 sufficient for protocols currently running on said network to
4 complete execution.

1 39. The article of manufacturing of claim 38, wherein said
2 protocols comprise one of a heart beat, join, death, or node
3 reachability protocol.

1 40. The article of manufacturing of claim 36, wherein said
2 predetermined period of time comprises an amount of time
3 sufficient for a protocol currently running on said network to
4 perform a predetermined number of retries plus a predetermined
5 amount of time between each retry, wherein after attempting said
6 predetermined number of retries, said protocol completes
7 execution.

1 41. The article of manufacturing of claim 40, wherein said
2 protocol comprises one of a heart beat, join, death, or node
3 reachability protocol.

1 42. The article of manufacturing of claim 36, wherein said
2 computer readable program code means for reconfiguring said one
3 node reconfigures without any communication to said node from
4 said at least one other node of said plurality of nodes.

1 43. The article of manufacturing of claim 36, wherein said
2 computer readable program code means for reconfiguring said one
3 node comprises computer readable program code means for
4 refraining from observing said change in topology at said one
5 node during a grace period, wherein said grace period comprises a
6 predetermined period of time sufficient to allow said at least
7 one other node of said plurality of nodes to exit a quiescent
8 state, and upon termination of said grace period, for observing
9 said change in topology at said one node.

1 44. The article of manufacturing of claim 36, wherein said
2 reconfiguration request results from addition or removal of a
3 node or of at least one other network to said network.

1 45. The article of manufacturing of claim 36, where said
2 reconfiguration request results from a change in address of a
3 node of said network.

1 46. The article of manufacturing of claim 36, wherein said
2 network is reconfigured without interrupting currently executing
3 protocols.

1 47. The article of manufacturing of claim 36, wherein said
2 network is reconfigured without a global synchronization
3 protocol.

1 48. The article of manufacturing of claim 36, further
2 comprising computer readable program code means for transmitting,
3 upon entering said quiescent state, a reconfiguration request
4 from said one node to said at least one other node, wherein
5 receipt of said reconfiguration request causes said at least one
6 other node to enter a quiescent state.

1 49. The article of manufacturing of claim 48, wherein said
2 reconfiguration request comprises one of a message having a
3 reconfiguration sequence identifier and a message having a
4 configuration sequence identifier different from a configuration
5 identifier of said one node.

1 50. The article of manufacturing of claim 36, wherein said
2 network comprises a plurality of interconnected computing
3 networks together implementing a distributed node and adapter
4 status monitoring system.

1 51. The article of manufacturing of claim 36, further
2 comprising computer readable program code means for preventing,
3 by said node when in said quiescent state, the execution of new
4 protocols by ignoring proclaim, join, node connectivity, and
5 group connectivity messages and by no longer monitoring heartbeat
6 messages.

1 52. The article of manufacturing of claim 36, further
2 comprising computer readable program code means for transmitting,
3 by said node when in said quiescent state, proclaim, heartbeat,
4 node connectivity, and group connectivity messages with a
5 reconfiguration sequence identifier to propagate reconfiguration
6 requests to said at least one other node.

* * * * *

RECONFIGURATION OF A NETWORK BY UTILIZING
A PREDETERMINED LENGTH QUIESCENT STATE

Abstract Of The Disclosure

5 A network having a plurality of nodes is reconfigured to
reflect a change in topology of the network. In particular, upon
receiving a reconfiguration request, each node enters a quiescent
state for a predetermined period of time sufficient to allow at
least one other node to also enter a quiescent state. Then, upon
10 termination of the quiescent state, the node is reconfigured to
reflect the change in the topology of the network without having
to check with any other nodes of the network. In other
embodiments, the predetermined period of time is sufficient to
allow currently executing protocols to complete execution as well
15 as to allow the transmission of reconfiguration requests for
propagating reconfiguration in the network.

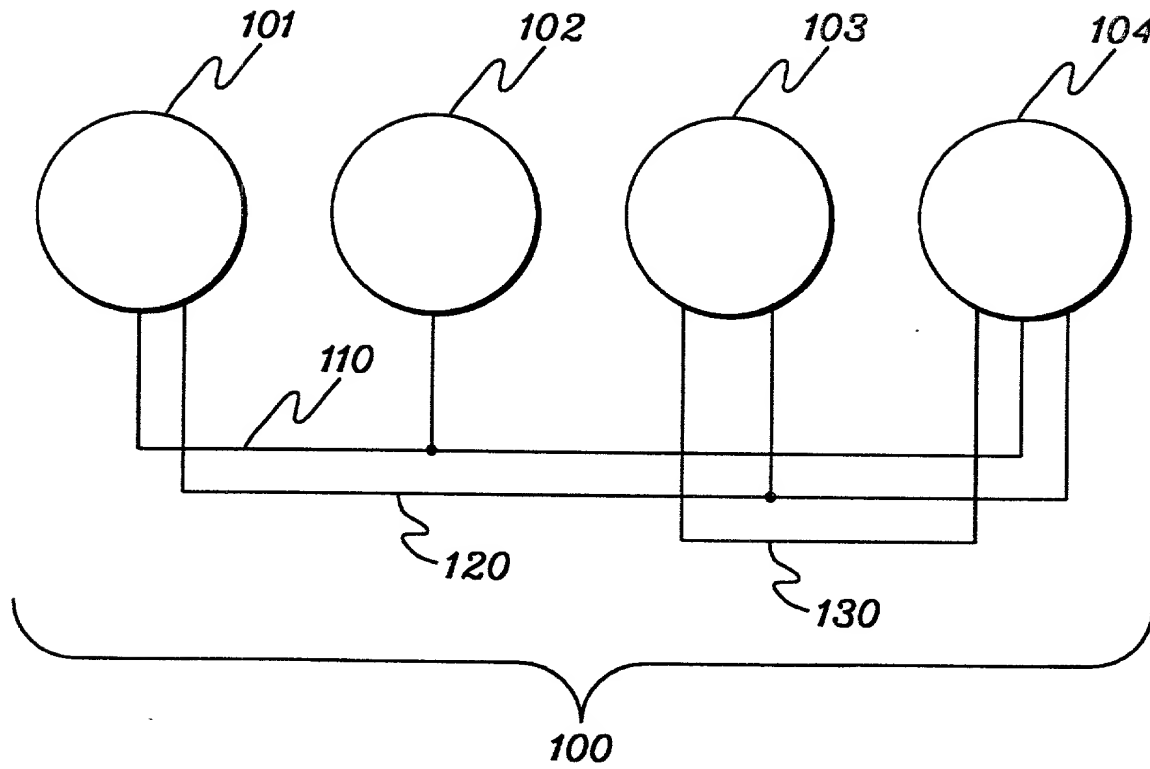


fig. 1

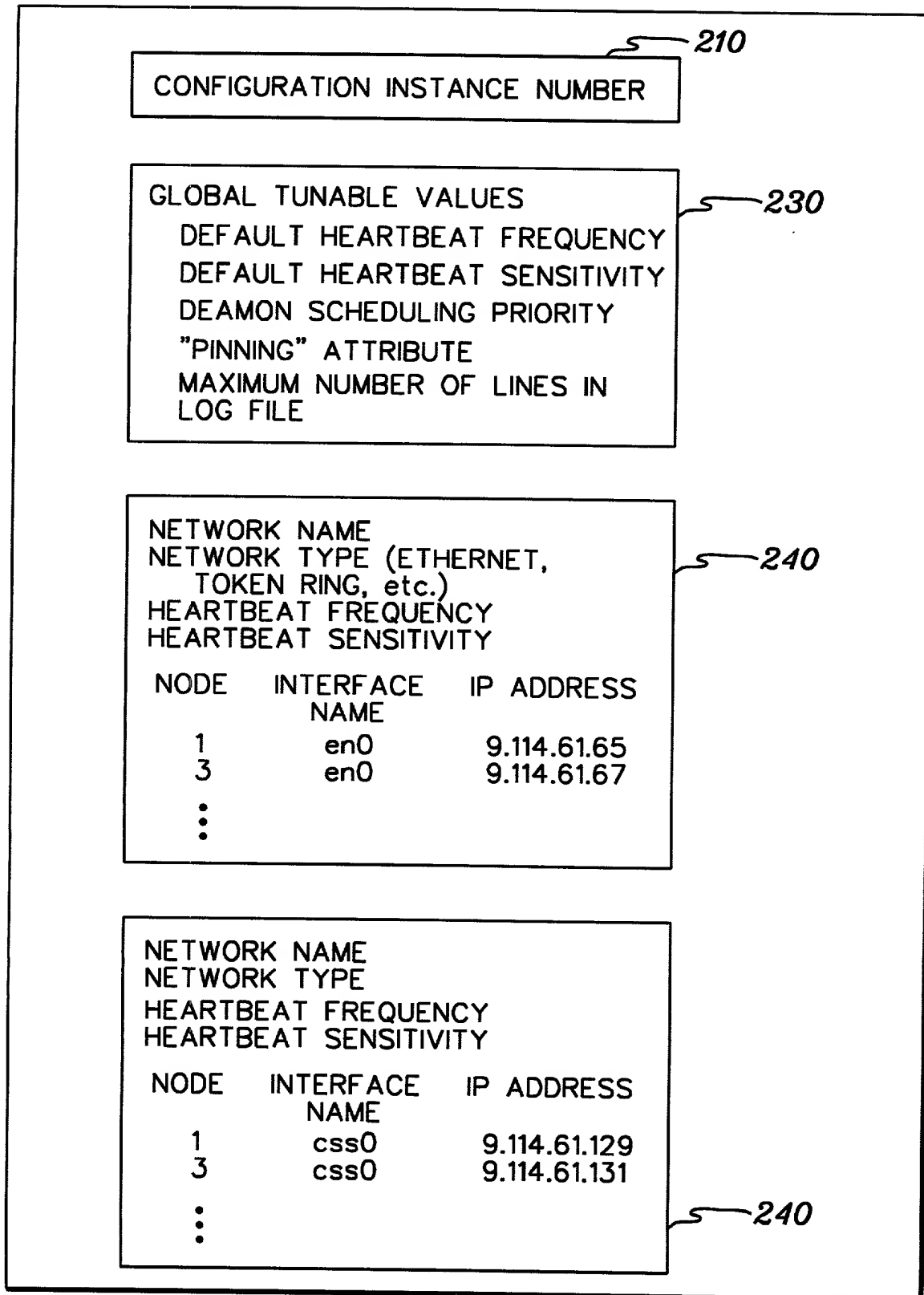


fig. 2

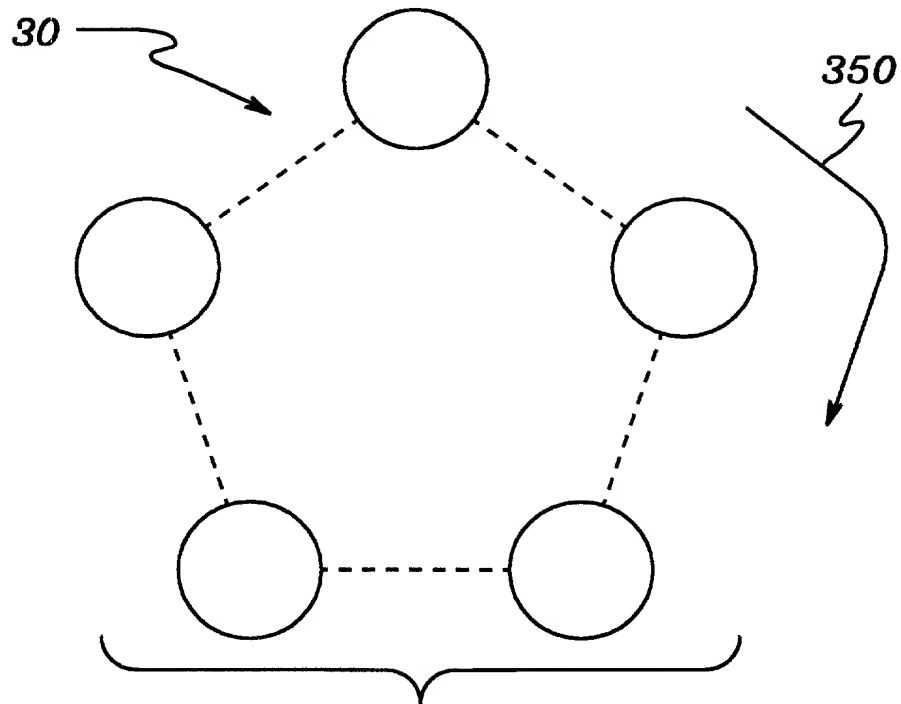


fig. 3

310

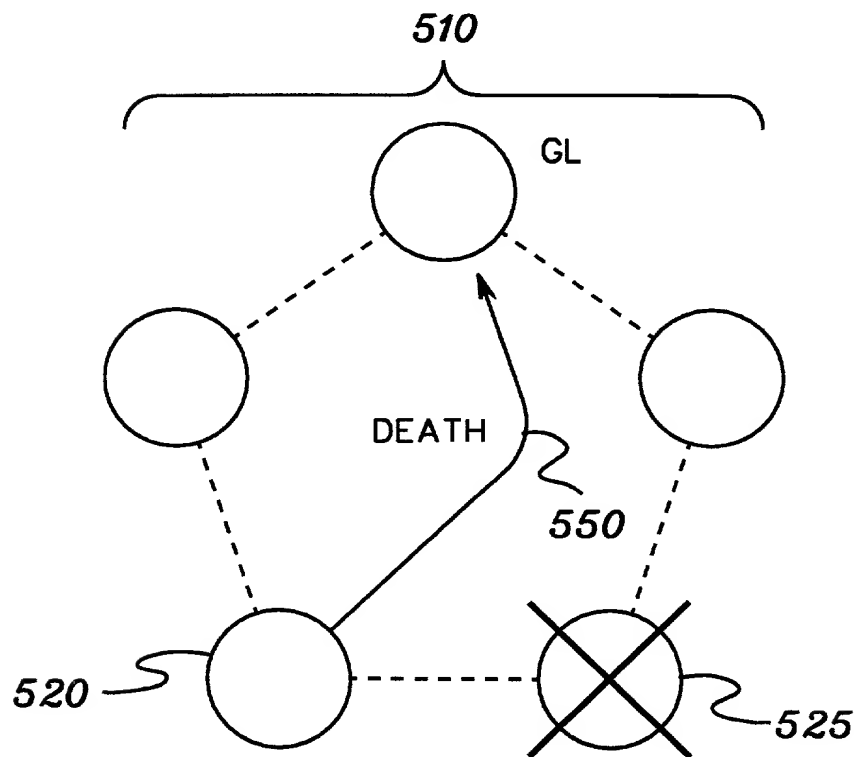


fig. 5

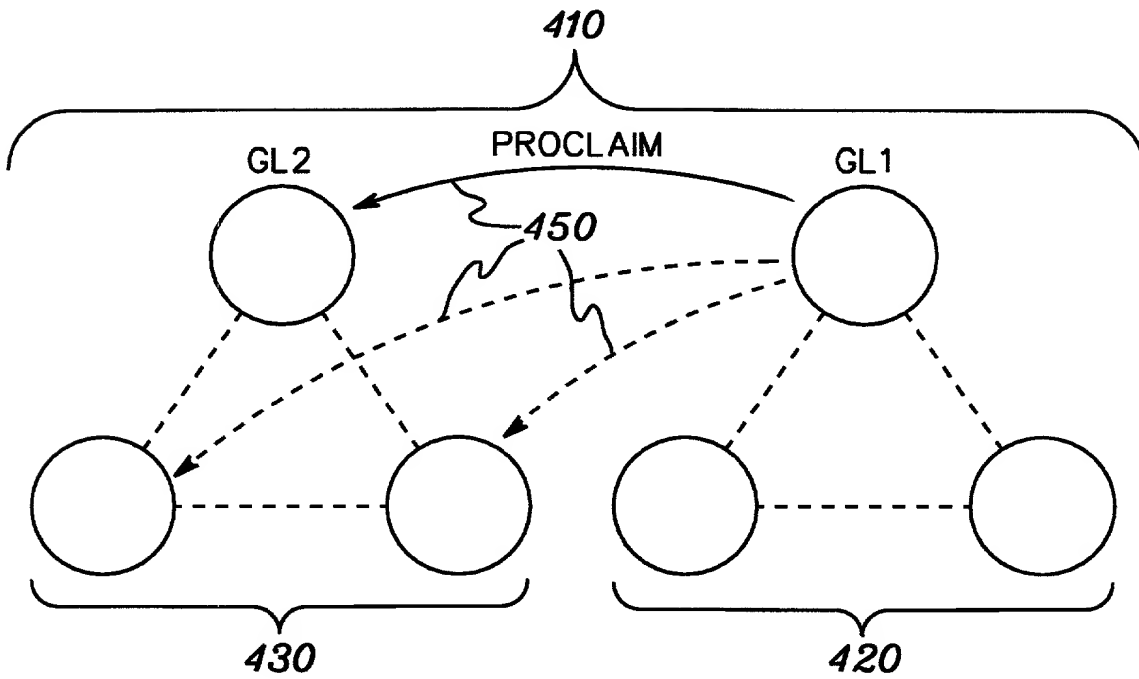


fig. 4a

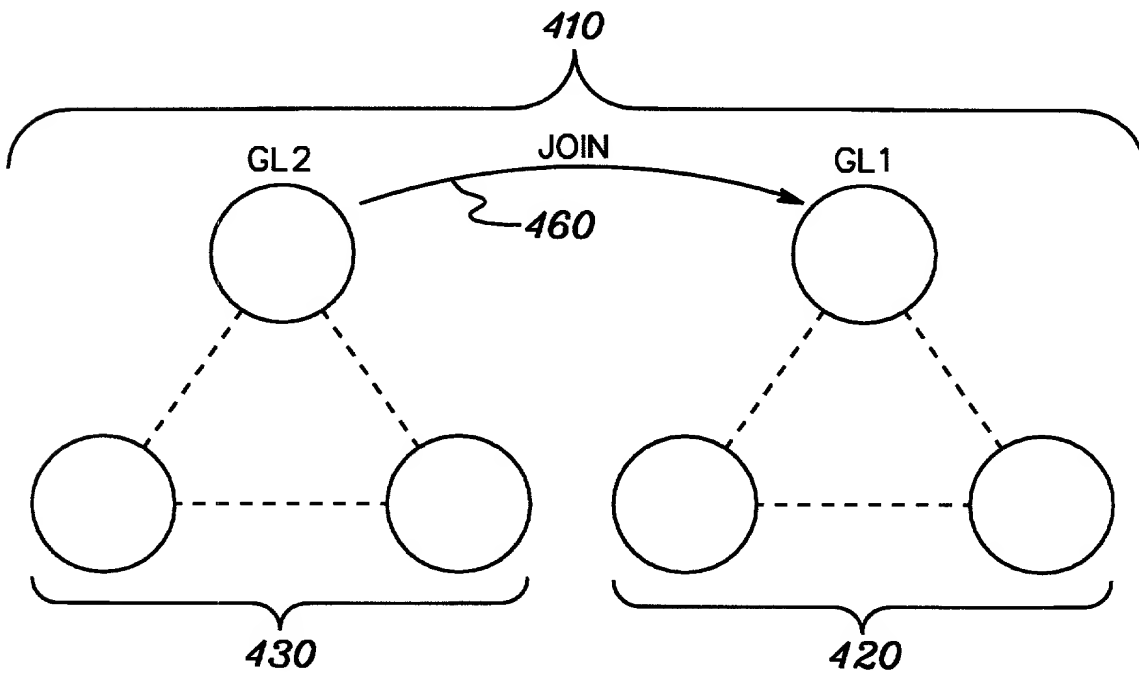


fig. 4b

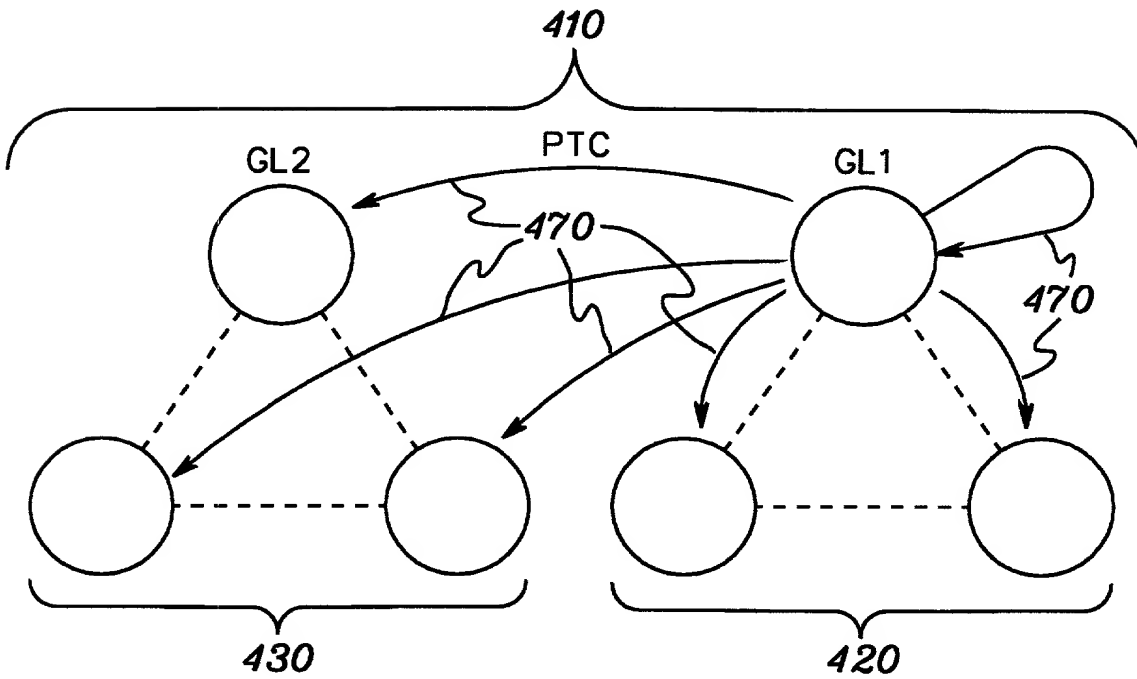


fig. 4c

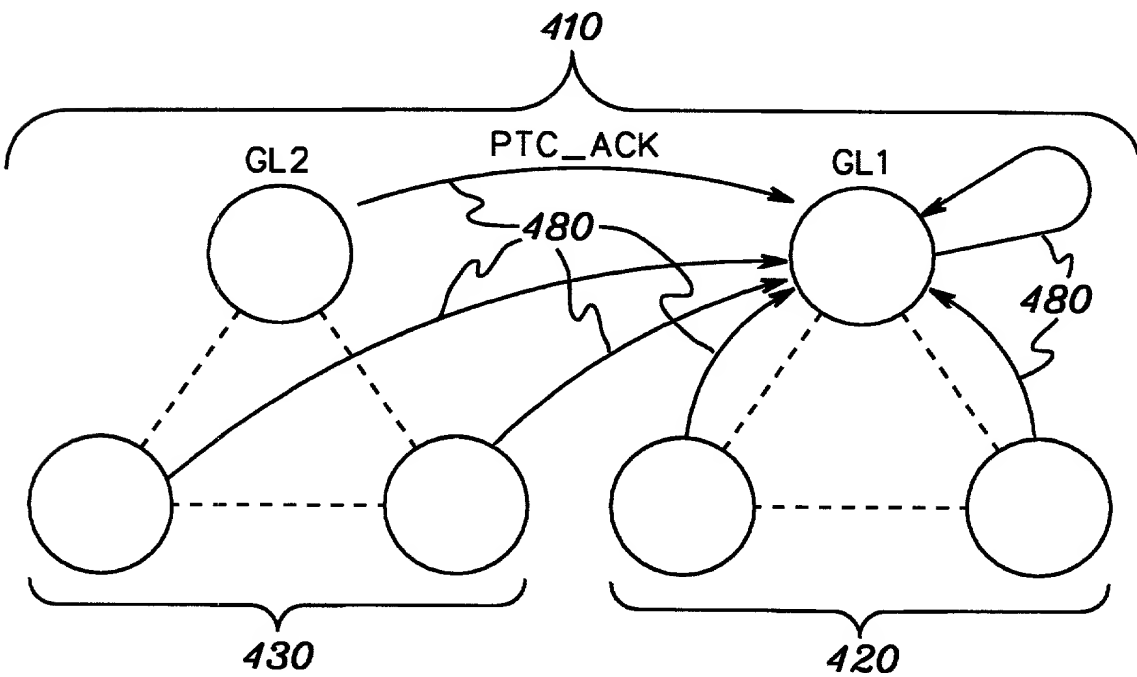


fig. 4d

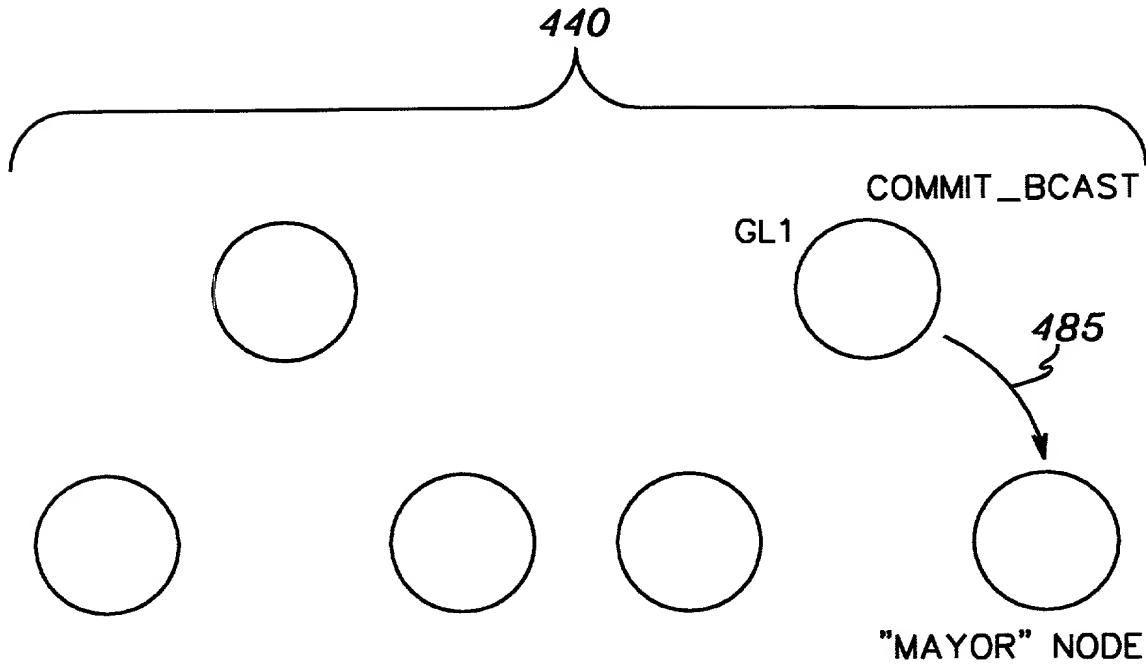


fig. 4e

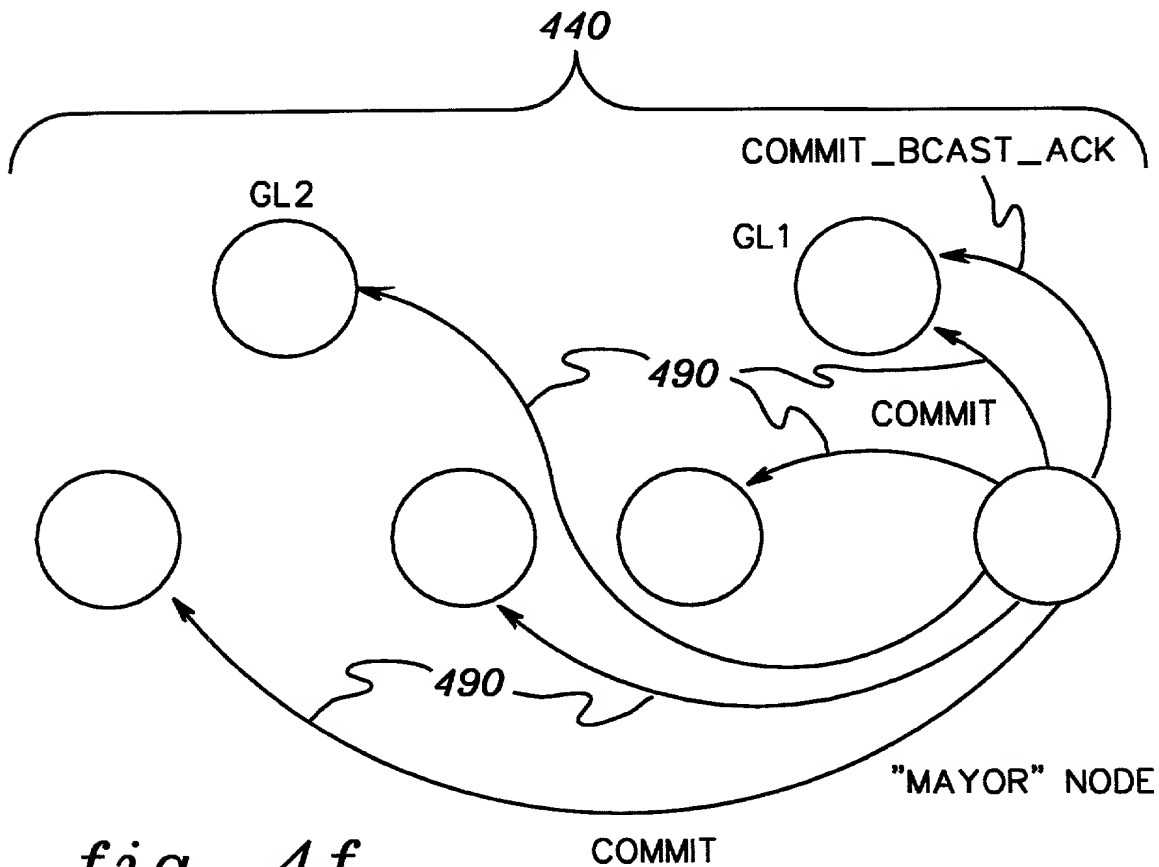


fig. 4f

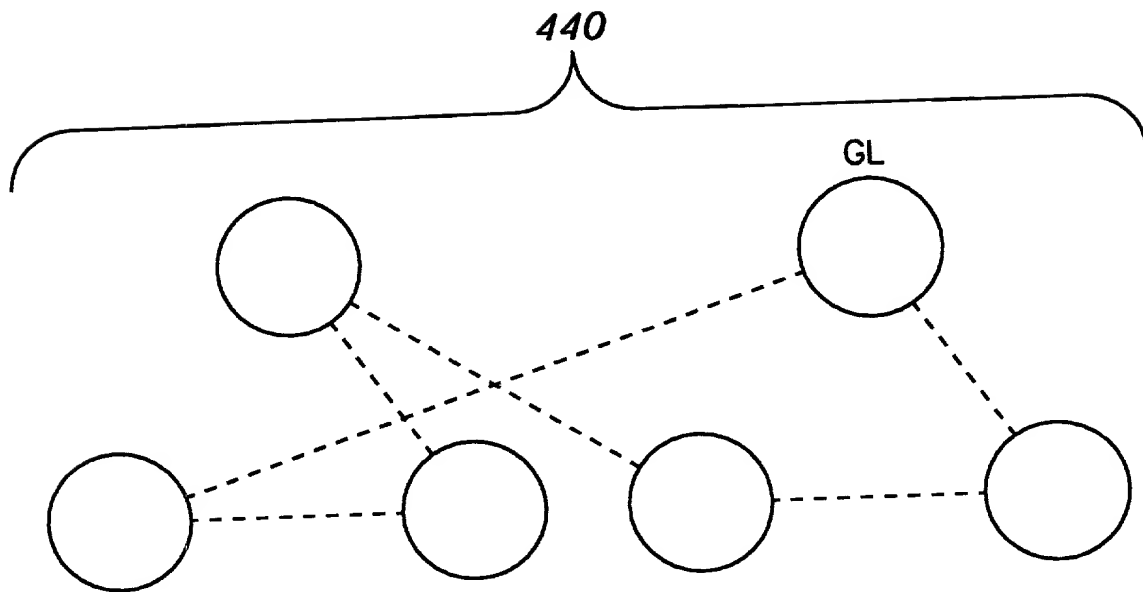


fig. 4g

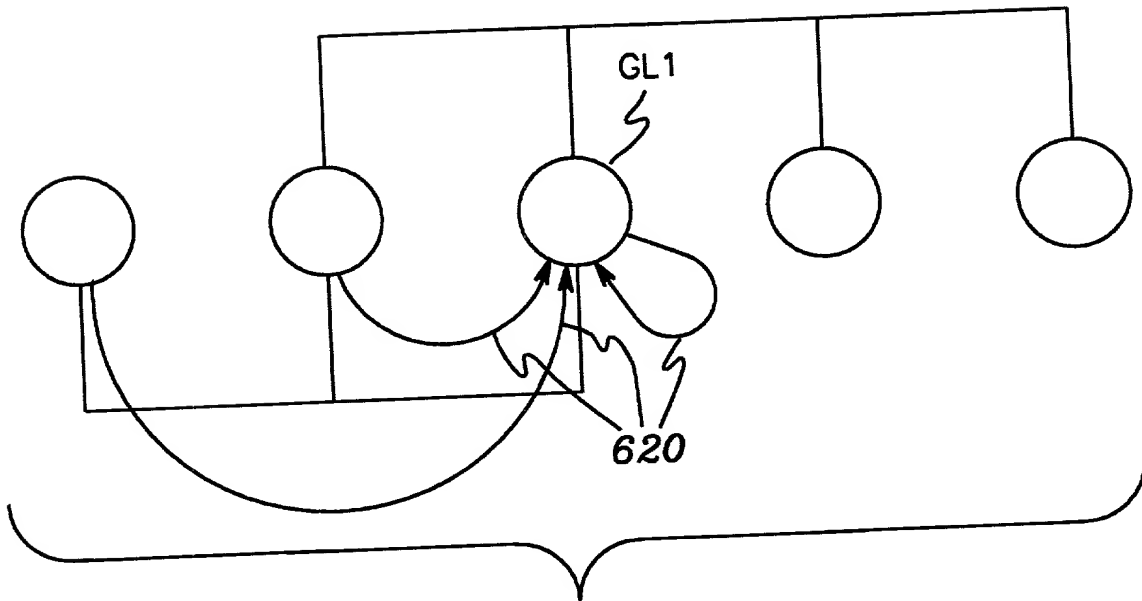


fig. 6a

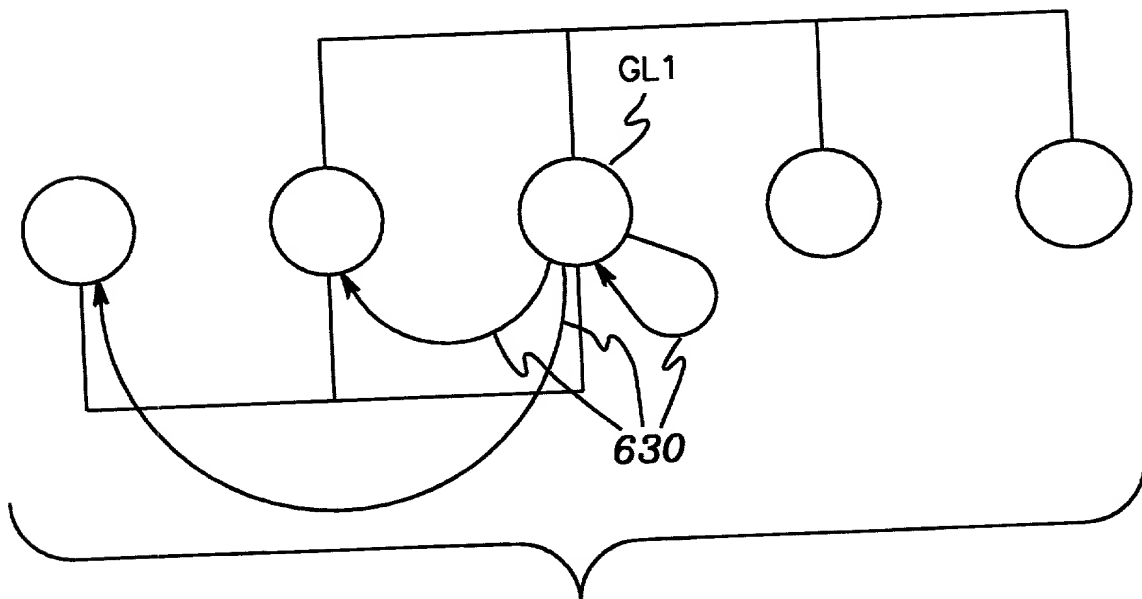


fig. 6b

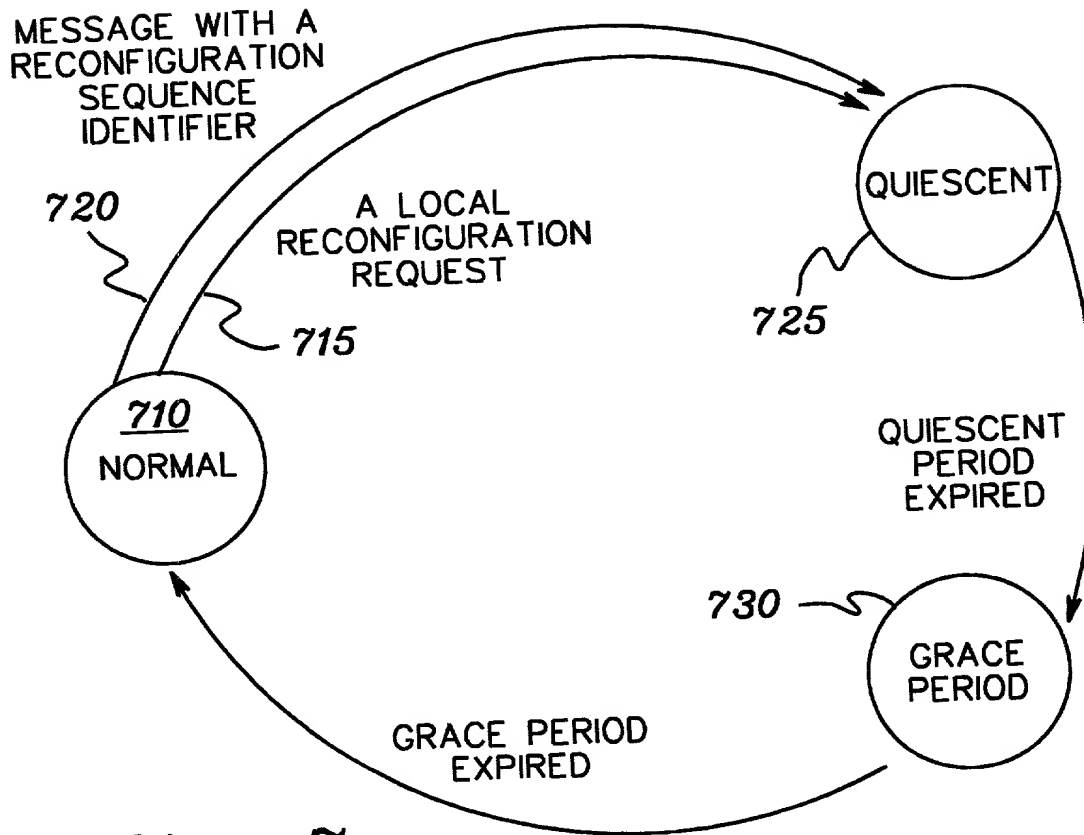


fig. 7

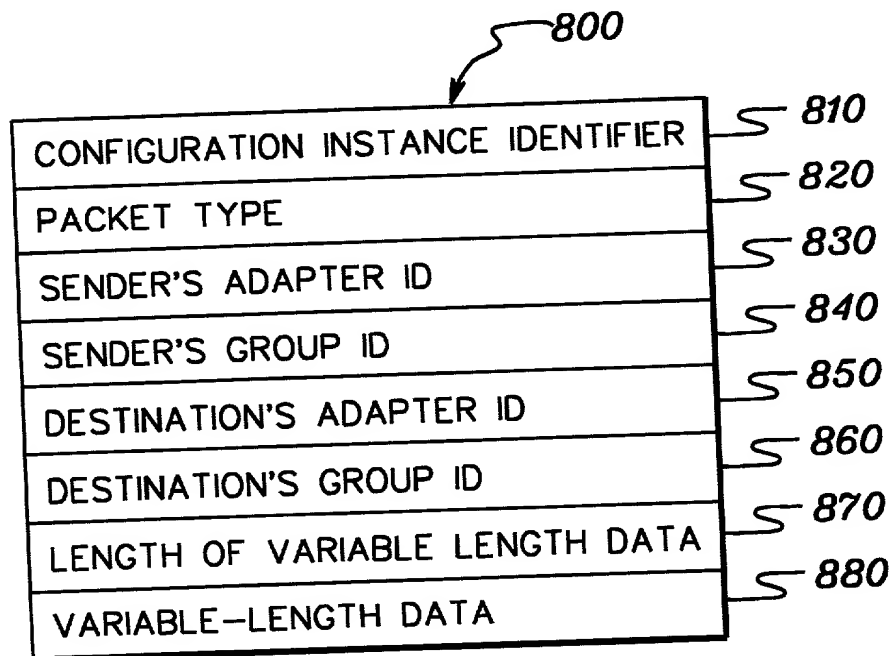


fig. 8

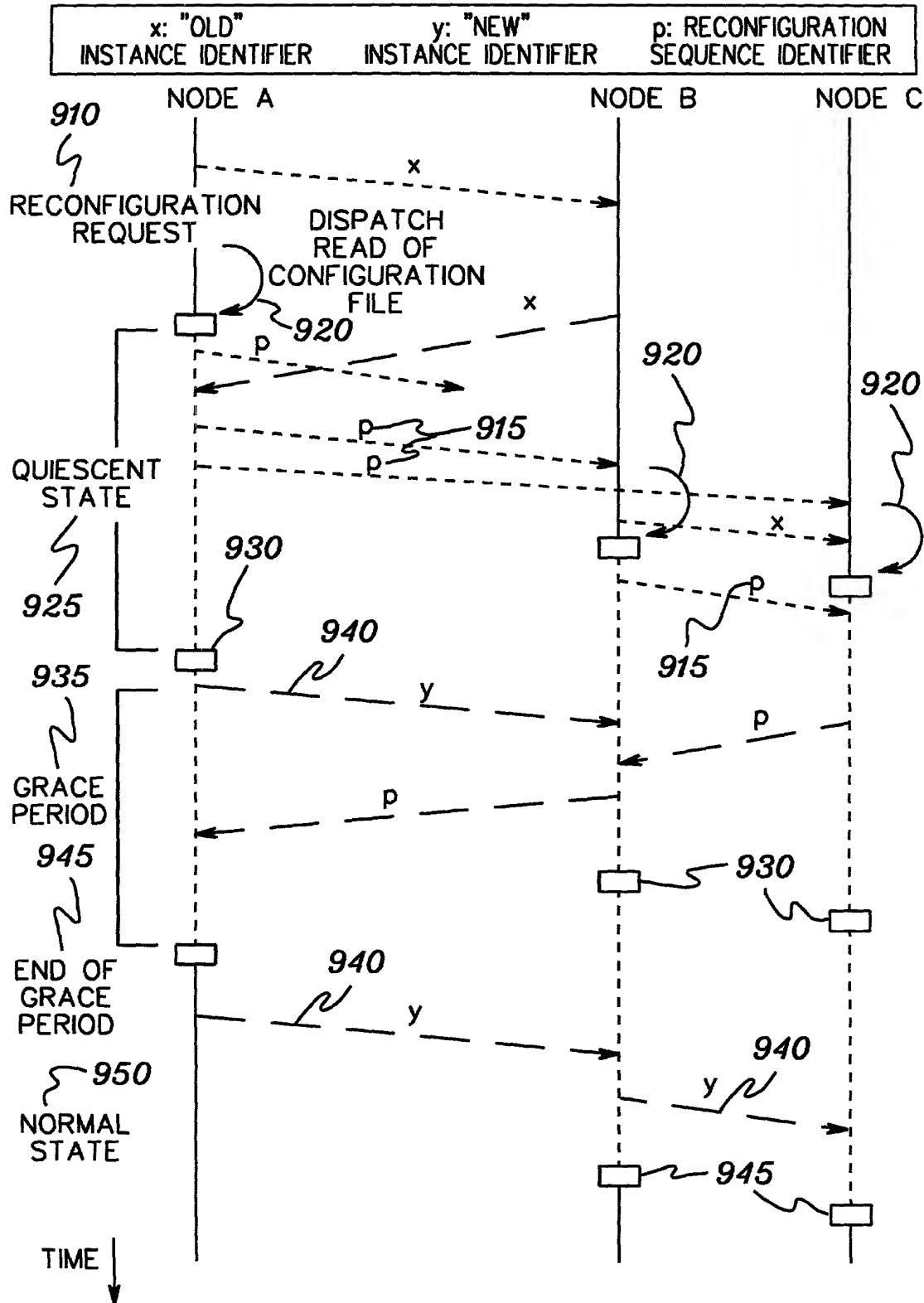


fig. 9

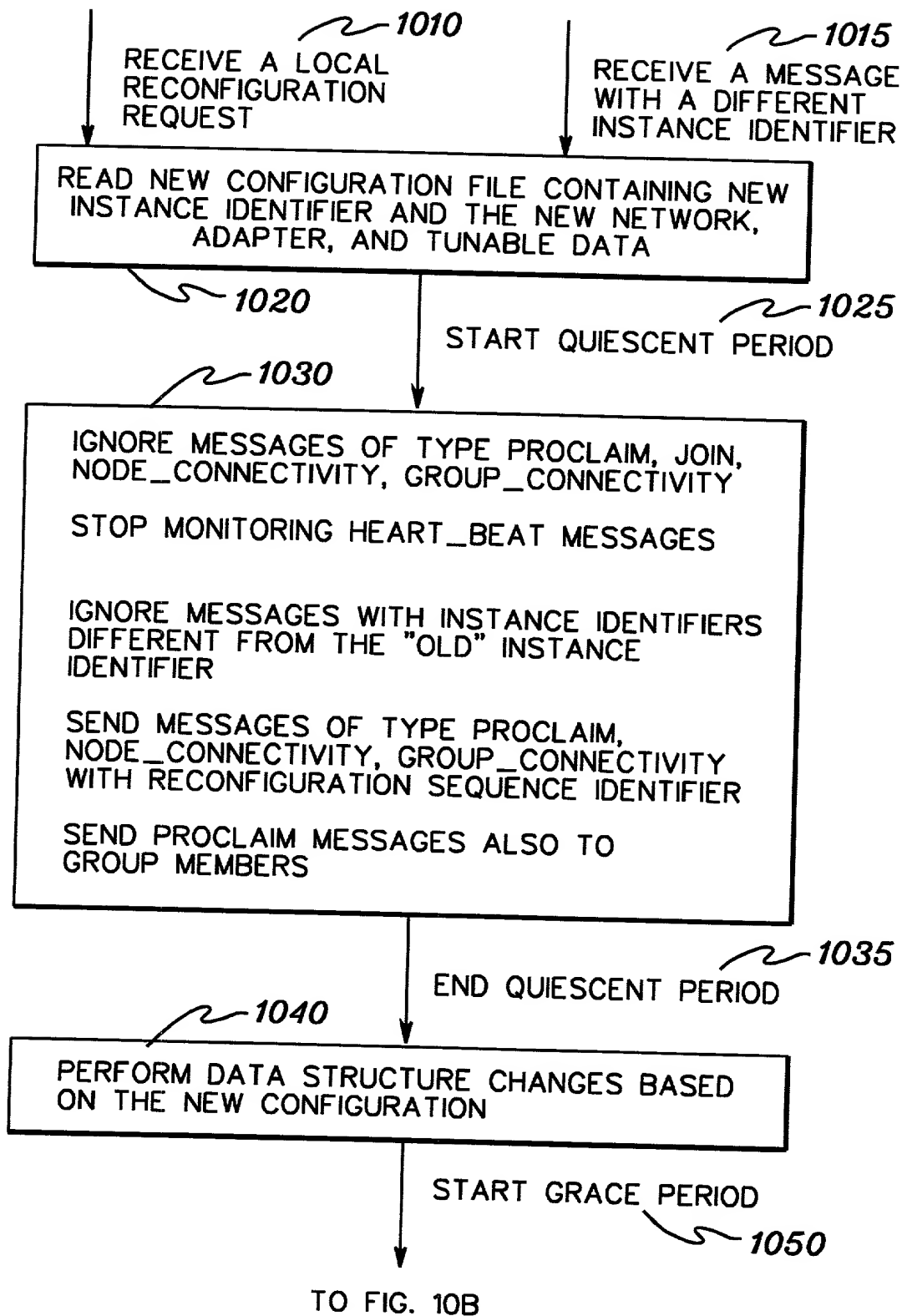


fig. 10A

FROM FIG. 10A

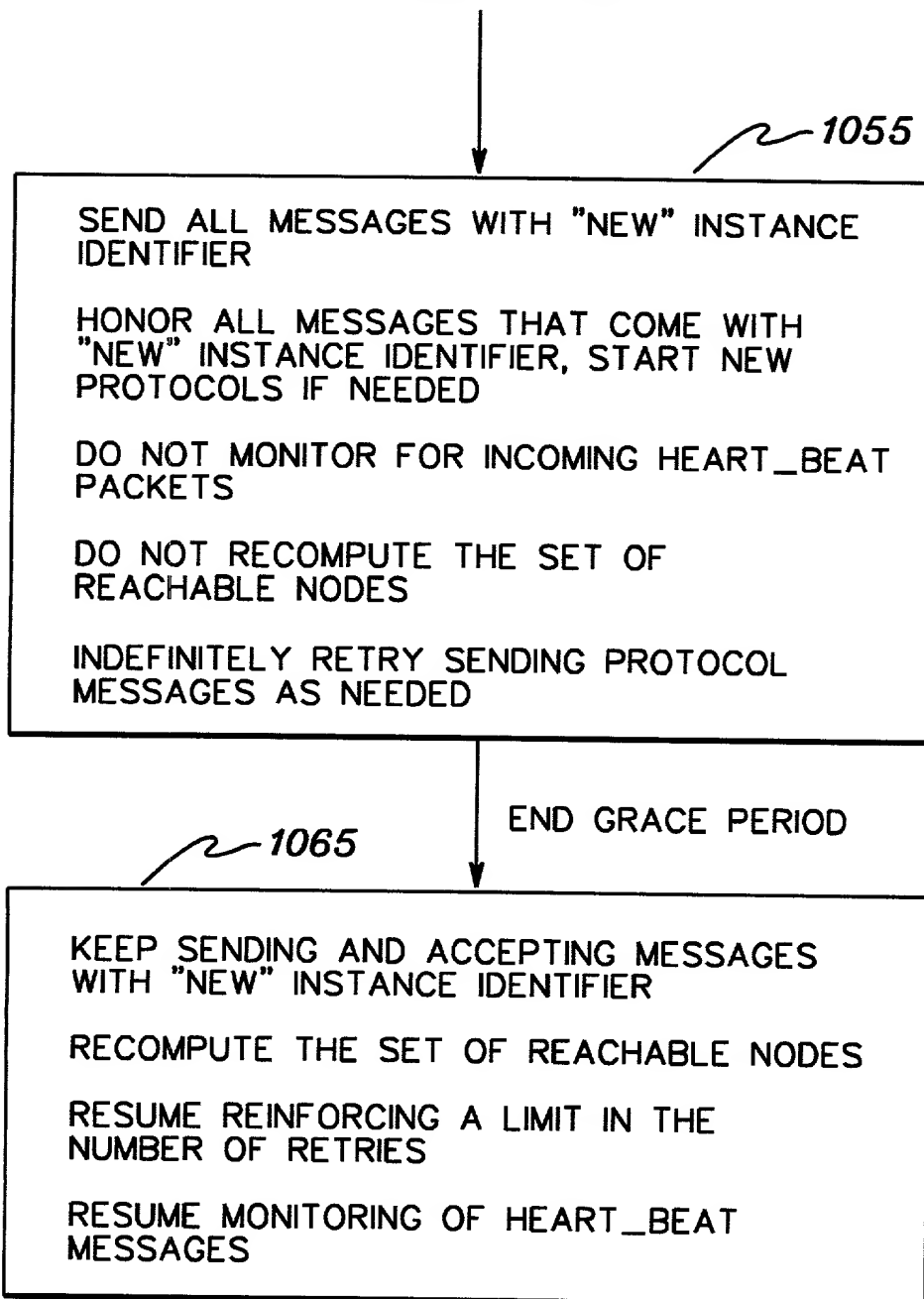


fig. 10B

Docket No.

PO9-99-067

Declaration and Power of Attorney For Patent Application

English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

RECONFIGURING A NETWORK BY UTILIZING A PREDETERMINED LENGTH QUIESCENT STATE

the specification of which

(check one)

☒ is attached hereto.

☐ was filed on _____ as United States Application No. or PCT International Application Number _____ and was amended on _____

(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

Priority Not Claimed

(Number)

(Country)

(Day/Month/Year Filed)

☐

(Number)

(Country)

(Day/Month/Year Filed)

☐

(Number)

(Country)

(Day/Month/Year Filed)

☐

I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional

(Application Serial No.)

(Filing Date)

(Application Serial No.)

(Filing Date)

(Application Serial No.)

(Filing Date)

I hereby claim the benefit under 35 U. S. C. Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C. F. R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

(Application Serial No.)

(Filing Date)

(Status)
(patented, pending, abandoned)

(Application Serial No.)

(Filing Date)

(Status)
(patented, pending, abandoned)

(Application Serial No.)

(Filing Date)

(Status)
(patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

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 Lynn L. Augspurger, Reg. No. 24,227
 William A. Kinnaman, Jr., Reg. No. 27,650
 Lily Neff, Reg. No. 38,254
 Marc A. Ehrlich, Reg. No. 39,966
 Lawrence D. Cutter, Reg. No. 28, 501

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Poughkeepsie, NY 12601³_{jk}	

Full name of fifth inventor, if any	
Fifth inventor's signature	Date
Residence	
Citizenship	
Post Office Address	

Full name of sixth inventor, if any	
Sixth inventor's signature	Date
Residence	
Citizenship	
Post Office Address	

Express Mail Label No.

Page 1 of

Docket No.
P09-99-067

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English Language Declaration

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the specification of which

(check one)

☒ is attached hereto.

☐ was filed on _____ as United States Application No. or PCT International Application Number _____ and was amended on _____ (if applicable)

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Prior Foreign Application(s)

Priority Not Claimed

_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/>
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/>
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/>

I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional

_____ (Application Serial No.)	_____ (Filing Date)
_____ (Application Serial No.)	_____ (Filing Date)
_____ (Application Serial No.)	_____ (Filing Date)

I hereby claim the benefit under 35 U. S. C. Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C. F. R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

_____ (Application Serial No.)	_____ (Filing Date)	_____ (Status) (patented, pending, abandoned)
_____ (Application Serial No.)	_____ (Filing Date)	_____ (Status) (patented, pending, abandoned)
_____ (Application Serial No.)	_____ (Filing Date)	_____ (Status) (patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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